

WELCH



MODEL 2 PHOTOMETER

maintenance manual



THE WELCH SCIENTIFIC COMPANY

FOREMOST MANUFACTURERS OF SCIENTIFIC EQUIPMENT

1515 Sedgwick Street

Chicago 10, Illinois

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WELCH

DENSICHRON

The High-Stability Line for
easier, more positive detection
and measurement of light.

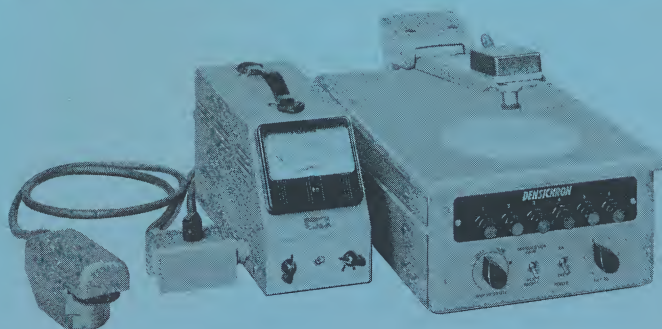
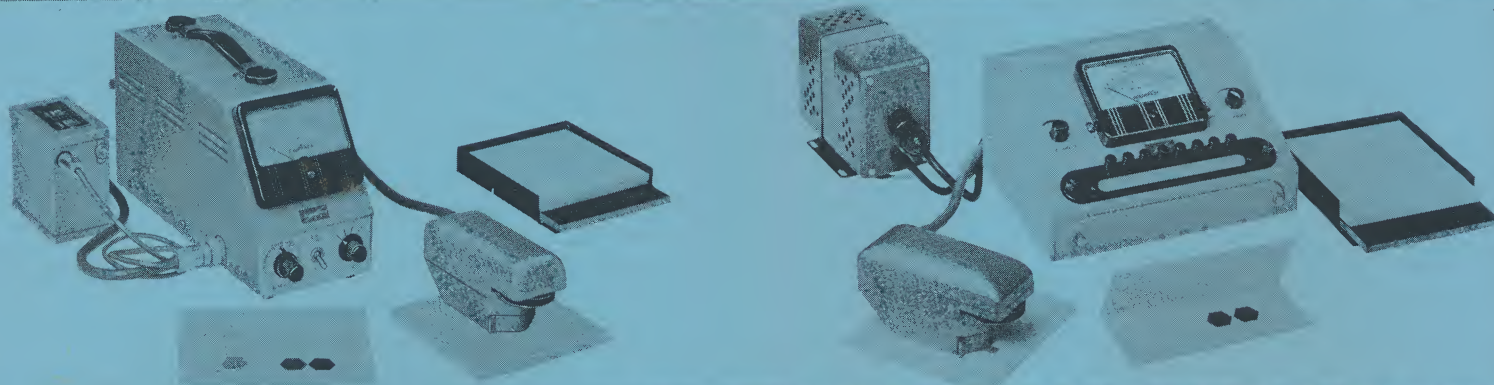
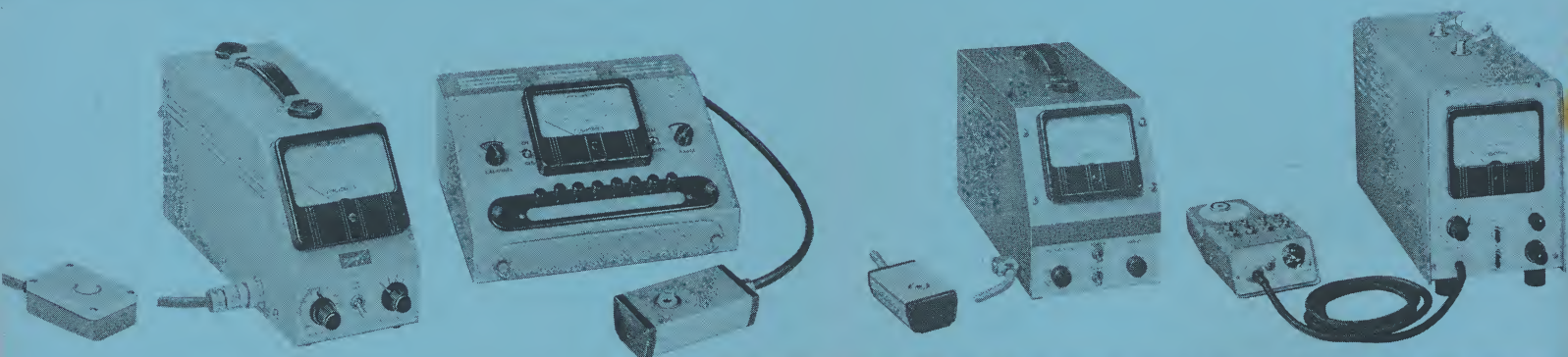


TABLE OF CONTENTS

SECTION I - THE DENSICHRON 2 PHOTOMETER

- A - General Description
- B - Accessory Equipment
- C - Installation (Effect on Performance)
- D - Electrical Design
- E - Mechanical Design

SECTION II - TEST EQUIPMENT & RECORDS

- 1 - Minimum Requirement
- 2 - Additional Desirable Equipment
- 3 - Records
- 4 - Procedure

SECTION III - PERFORMANCE

- 1 - Meter Zero Check
- 2 - Warm-Up
- 3 - Hum Adjustment
- 4 - Microphonics Tests
- 5 - Set-up for further tests
- 6 - Drift and Fatigue
- 7 - Multiplication or Range Test
- 8 - Photometric Sensitivity
- 9 - Linearity
- 10- Voltage Compensation
- 11- Push Button Controls
- 12- External Attenuators
- 13- Miscellaneous
- 14- Variation Due to Application

SECTION IV - SYMPTOMS - THEIR CAUSE AND REMEDY

SECTION V - PARTS LIST AND SCHEMATIC DIAGRAM



Fig. 1 - The Densichron 2 Photometer

SECTION I - THE DENSICHRON 2 PHOTOMETER

A. General Description

The Densichron 2 Photometer is a light meter of high sensitivity. The patented Magnephot principle (U. S. Patent 2,424,933), which involves modulation of the electron path in a phototube, permits use of AC amplifier techniques and results in a photometer which is both stable and sensitive. This instrument operates only on 115 volts at 60 cycles.

The amplifier is a high gain, low noise, narrow band AC amplifier. The meter circuit is located in the negative feedback on the last stage and the meter scale has been stepped to compensate for the non-linearity of the diodes in this circuit. All components, including the probe and probe cable, are carefully selected, positioned, and shielded to provide minimum hum pickup and signal attenuation. The combination results in a photometer with excellent stability, accuracy, and sensitivity.

The instrument is provided with front panel controls, as shown in Figure 1. The meter is calibrated in Optical Density (the center scale), reading "0" density (or 100% transmission) toward the right. The extreme left position (just beyond 2.0 density) is the meter zero and is used in some of the adjustment procedures.

The range switch provides decade stepping of the sensitivity and is used when reading densities greater than 1.0 or when standardizing at this range switch position to get the correct density, i.e., when standardized on range zero, a density of 2.54 will be .54 on the meter plus position 2.0 on the range switch.

The calibration control is used to adjust the sensitivity to a value which produces the necessary signal level to read a calibrated density at the light level provided. The position marked "10" on the dial is the highest sensitivity position.

Also on the front panel are the power switch, just to the left of the meter, and the dial light switch, just to the right of the meter.

A row of 8 selector buttons are located directly below the meter and a row of 7 dual potentiometers are located inside the front cover and are the adjustment for the push button controls. The push buttons constitute a means of changing the gain of the amplifier in discreet amounts which are adjustable to suit the requirement. Button #8, on the extreme right, is always directly connected to provide maximum sensitivity. All other buttons have their own dual potentiometer within the range of the photometer.

The dual potentiometers are of the concentric shaft screw driver adjust type. A special tool is supplied to make this adjustment; it is held in its storage position inside the potentiometer cover by a spring clip. If kept in this place it will always be handy and won't get lost. The pin end of the tool is used to make a "fine" adjustment and the small end for a "coarse" adjustment. Access to the controls is shown in Fig. 3.

The back panel is shown in Fig. 2. The various controls and connections are clearly identified on the name plate.

B. Accessory Equipment

Following is a list of accessories which are available for use with the Densichron 2 Photometer. Refer to general catalog for description.

Cat. No. 3831P	- Photometric set
Cat. No. 3834L	- Constant wave from voltage regulator
Cat. No. 3844A	- Filter Wheel
Cat. No. 3844C	- Integrator Attachment
Cat. No. 3853A	- Transmission Light Source - no filters
Cat. No. 3853D	- Transmission Light Source with filters
Cat. No. 3853G	- Remote Attenuator Cable



Fig. 2 - Rear View Showing Adjustment and External Accessory Location

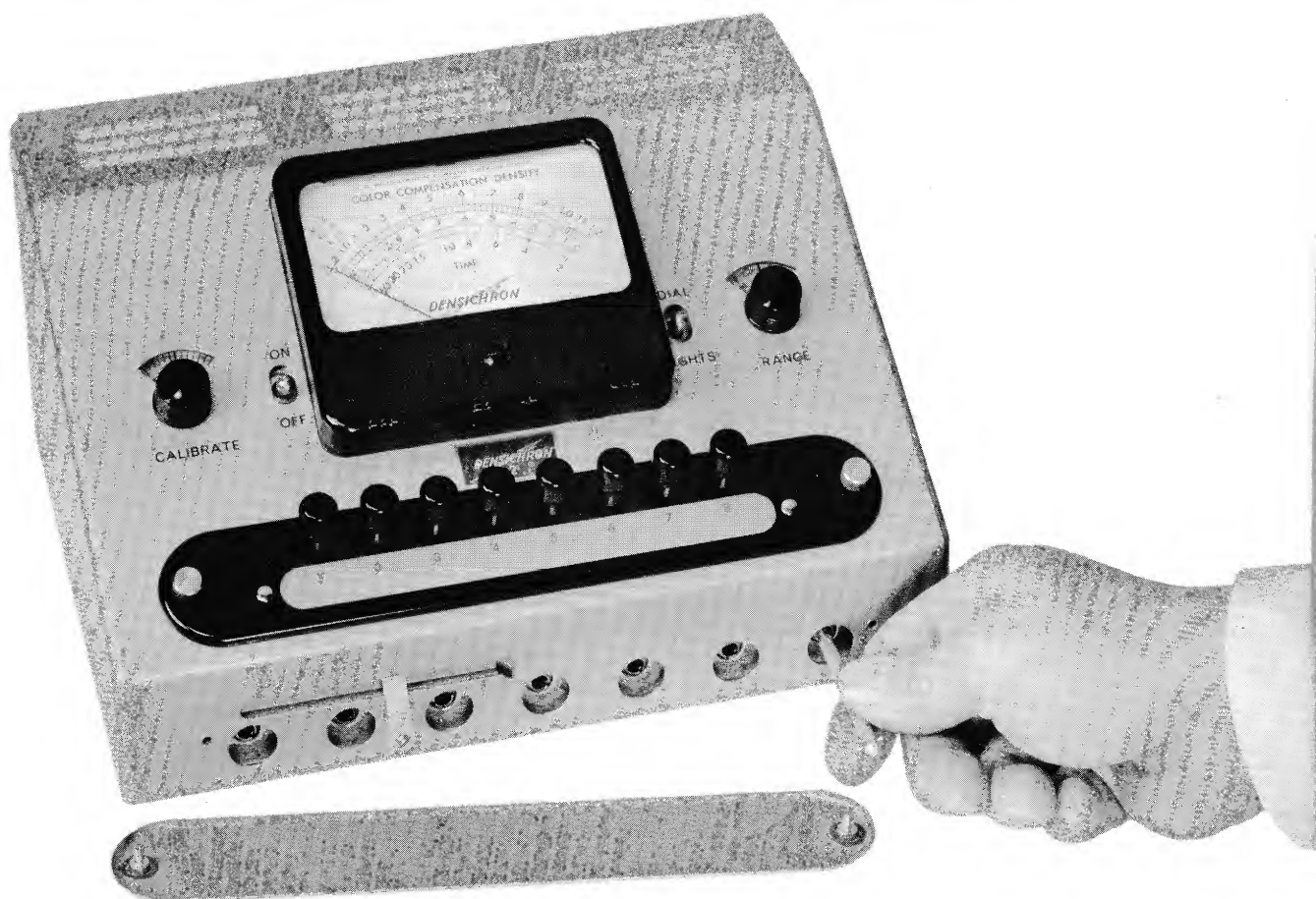


Fig. 3 - Front View Showing Adjustment of Push Button Controls

C. Installation

The performance tests and values described in Section III are those that represent an ideal or laboratory set of conditions. In actual operation such conditions seldom exist and some conditions tend to degrade the performance. Here are a few things to watch for:

1. Excessive line voltage fluctuations will sometimes cause a drift in the meter reading or fluctuations of the pointer. Inductive loads, or large resistive loads that are frequently switched on and off, cause these line voltage variations. Also the act of switching these loads causes a surge in the line which can affect the meter reading.

If the line voltage varies beyond the 105 to 125 volt range, or if surges in the line are causing trouble, the use of a Voltage Regulator will improve performance. Specify: Cat. No. 3834L Constant Wave Form Voltage Regulator.

2. Lamp intensity is a critical part of stability characteristics. A 1% change in lamp voltage will cause a 3.5% change in luminous output of the lamp. A voltage regulator for the lamp is practically a necessity.

Welch Densichron Light Source and Reflection Head are equipped with properly designed regulators. Any other source should be checked to be sure that lamp intensity is controlled within the limits of the requirements.

3. Industrial dirt can be the source of trouble. Paper lint and starch are the most frequent offenders. A coating of dirt in the lamp, lenses, and filters of the optical system will cause an apparent loss of sensitivity due to light absorption and linearity error due to stray light. Obvious solution is frequent cleaning of the optics, if dirt is a problem.
4. High frequency interference is a problem in a few unusual locations. If the instrument is used within a few blocks of a large TV Transmitter or Radar tracking station, check to be sure this is not a problem. Pickup of this sort will be evidenced by excessively high hum level.

D. Electrical Design

In the Densichron 2 the Magnephot system modulates magnetically the space current in the phototube by applying a 60 cycle alternating magnetic field across the electron beam in the tube. This deflects the electrons from their normal path between the cathode and anode. The output from the tube is thus changed from its usual steady value (for unchanging luminous flux) to a pulsating output with a frequency of 120 pulses per second.

This output is directly proportional to light intensity and is amplified by a stable high gain AC Amplifier tuned to 120 cps. The random noise effects normally present at high sensitivities are filtered out by the narrow band pass amplifier and the only signal indicated by the meter is that resulting from the modulated output of the phototube.

Figure 4 is a block diagram of the Densichron 2, and shows the functional sections of the instrument and the wave form of the signal at different points in the amplifier.

A complete circuit diagram is found at the end of these instructions. On the circuit diagram each component is designated and these designations are used as reference numbers throughout this instruction.

1. The Input Circuitry:

In the Densichron 2, a volt 60-cycle current from the amplifier power supply is applied to the magnet coil (L-1) this alternately permits electrons to pass from the phototube cathode to the Anode producing the 120 cps. pulsed DC output. This AC signal is fed through a high impedance load (R-3) and a coupling condenser (C-3) to the grid of the first stage (V-1) of the amplifier. The values of the load resistor, grid resistor, etc. have been chosen to obtain a large signal

and a favorable signal to noise ratio, at an anode voltage which will not introduce too much phototube drift. The Anode voltage for Densichron 2 should be between 12 and 16 volts. The input impedance to the first stage is about 8 megohm. This is a little less than the calculated 10 megohm due to the capacity of the probe cable.

Proper shielding of the signal leads is very important, since any 120 cycle pickup will pass through the narrow band pass filter and appear at the meter as error. Particular care is necessary in handling the 60-cycle AC leads to the magnet. They are shielded in the cable and grounded in both the probe and the Amplifier chassis.

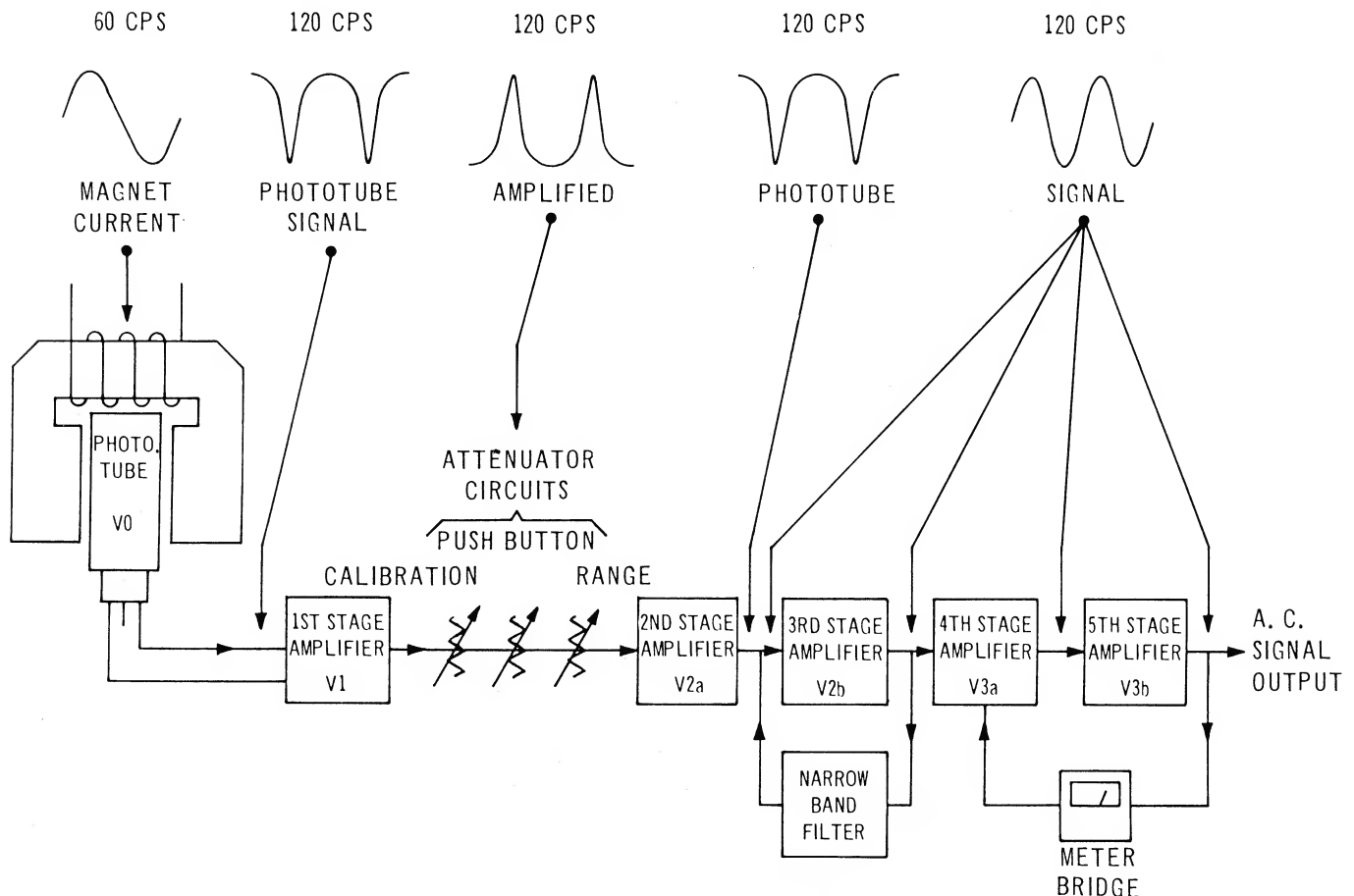


Fig. 4 - Block Diagram of Densichron

2. Attenuators:

The Densichron 2 contains a bank of signal attenuators between the first and second stages which are used as factory adjustments and/or operator adjustments. The circuitry is clear on the diagram. A 3-wire phone jack provides the means of connecting remote attenuators in the circuit.

3. Electrical Filter:

A tunable choke with RC components is arranged in a feedback loop around the third stage of the amplifier. The choke is tuned to provide high impedance to 120 cps. and low impedance to all other frequencies. Thus all but the 120 cps. signal is filtered out and all that reaches the 4th stage is a clean sine wave of 120 cps.

When Adjusted at the Factory:

1. With all controls set for maximum sensitivity, a 120 cps. 150 micro volt signal is fed into the grid of the first stage (V-1) and the feedback potentiometer (R-27) is adjusted so the meter indicates full scale. This compensates for variations in amplification factor, D. C. voltages, etc. caused by amplifier components.
2. A specific value of light (see Section III) is applied to the phototube (VO) and the internal sensitivity control (R8) is adjusted so that the meter again reads full scale. This compensates for variations in phototube sensitivity and input impedance.

Thus, each Photometer leaves the factory with the same photometric sensitivity when used to measure white (tungsten) light. Some variations will be noticed when reading colored subjects (phototubes do not have identical spectral response characteristics).

4. The Meter Circuit:

The 120 cps. output from the 5th stage (V-3b) is fed back into the cathode of the 4th stage (V-3a), thus stabilizing the amplifier. A full wave diode rectifier bridge is inserted in this feedback loop and a one ma. 500 ohm-meter placed across the bridge. A condenser is placed across the meter to increase its time constant which reduces its response to transients.

The diode response is not quite linear with signal level and the meter scale has been "warped" to compensate for this non-linearity. However, since this is done on a statistical average basis, small differences in diodes and meters will be noticed. A dual potentiometer is used in 2 legs of the diode bridge and shifts the operating point of the diode. Thus the resistance in the bridge is selected to cause the meter to read 0 density and 1.0 density very accurately. Residual midscale errors are negligible.

Another potentiometer is placed in the Cathode of the 4th stage to control the amount of feedback. This, in effect, adjusts the gain in the 4th and 5th stages to compensate for component variations anywhere in the amplifier. This potentiometer should be set to make the meter read full scale when a 150 micro volt 120 cps. signal is fed into the grid of the first stage.

5. The Output Signal:

A five pin receptacle (S5) is provided to utilize the 120 cps. signal for recorders, external controls, etc. However, this signal can only be used in conjunction with a high impedance load (above 10 megohms) since loading the output will affect the meter feedback loop.

6. The Overall Amplifier:

The Amplifier itself is a carefully designed AC Amplifier providing a rugged serviceable instrument. Adjustments are provided to compensate for most variations in components. Some of the components are selected for specific characteristics and all of the tubes are pre-aged to be sure of their reliability.

E. Mechanical Design

The mechanical design is described by the photographs which follow. If you read the instructions for dismantling as you study the photographs, you will acquire a clear understanding of the design and the location of the components identified on the circuit diagram.

1. The Amplifier:

- a. Turn the Amplifier upside down and remove 4 screws holding the bottom cover (see "A" Fig. 5).

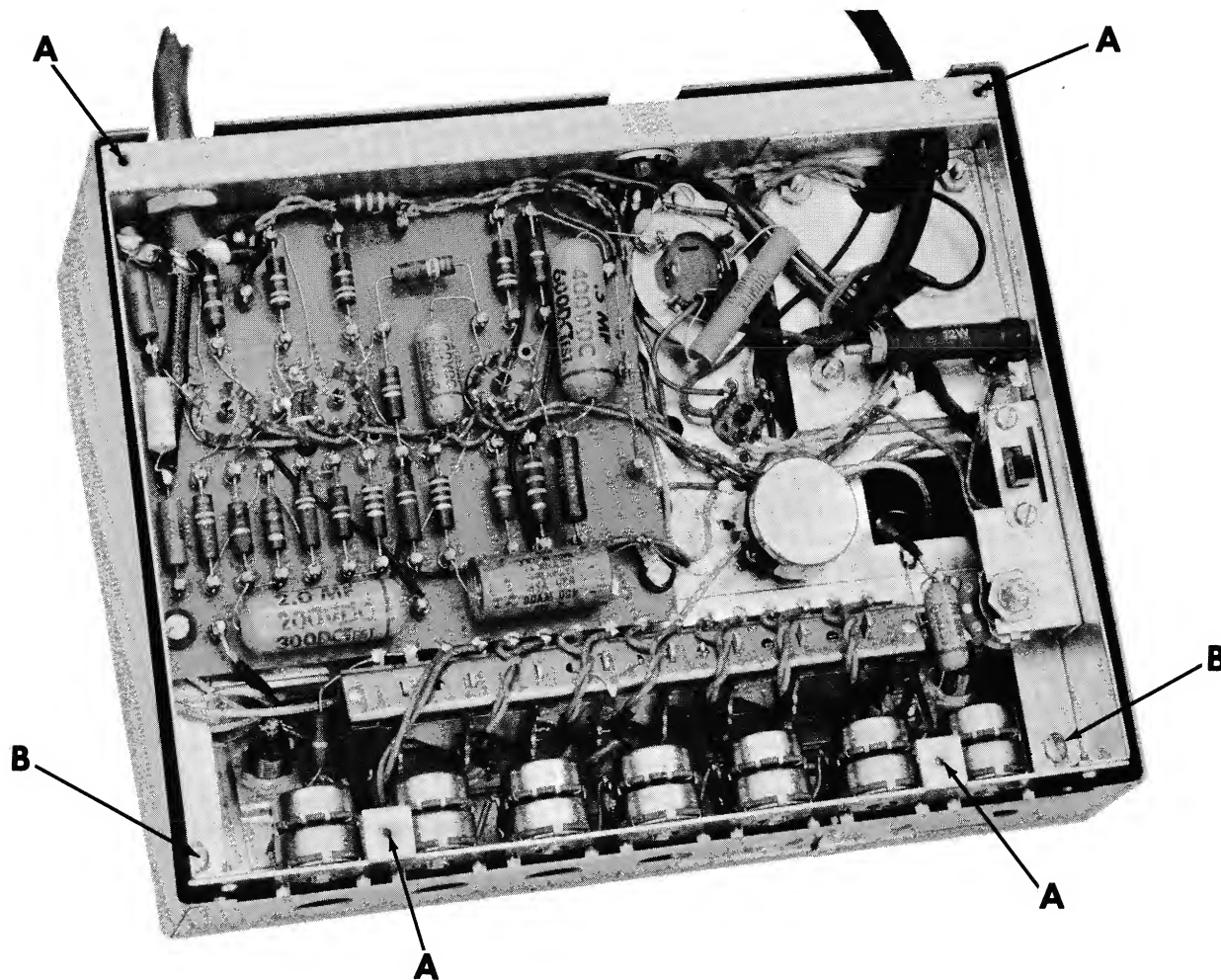


Fig. 5: Bottom view cover removed.

- b. Remove 2 screws (see "B" Fig. 5) and set aside.
- c. Turn Amplifier over (right side up) and remove all knobs, including push button.
- d. Remove Push Button Escutcheon.
- e. Remove case by upward and forward motions (don't go so far that the meter leads become taut (see Fig. 6).
- f. Disconnect meter leads at the meter.

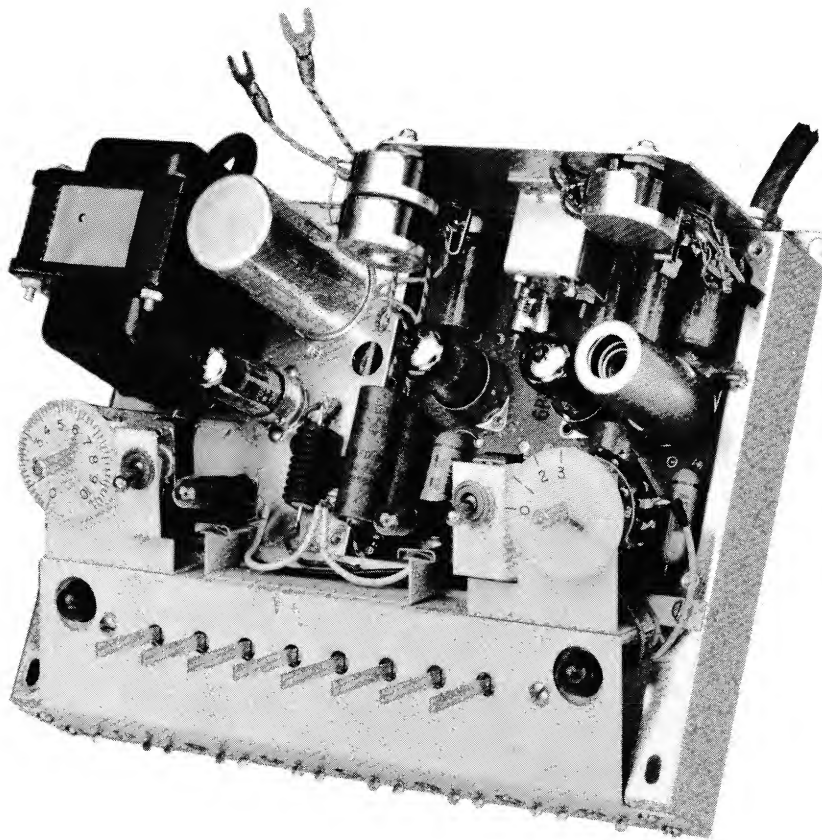


Fig. 6: Top view of Chassis - Case removed.

2. The Probe:

- a. Remove 2 screws, "A" in Fig. 7, and one screw "B" in Fig. 7.
- b. Pull Phototube assembly out of case at cable end (see Fig. 7).

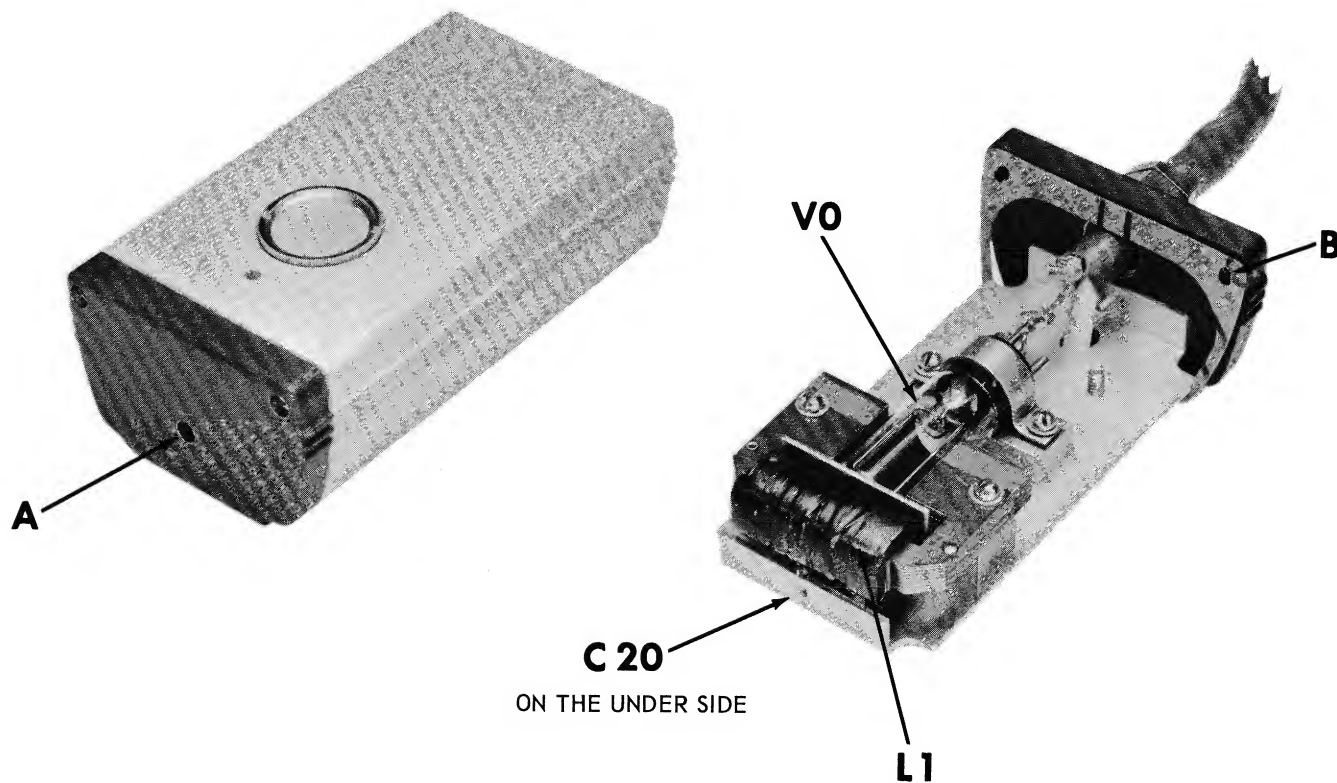


Fig. 7: View of Probe Elements open for servicing.

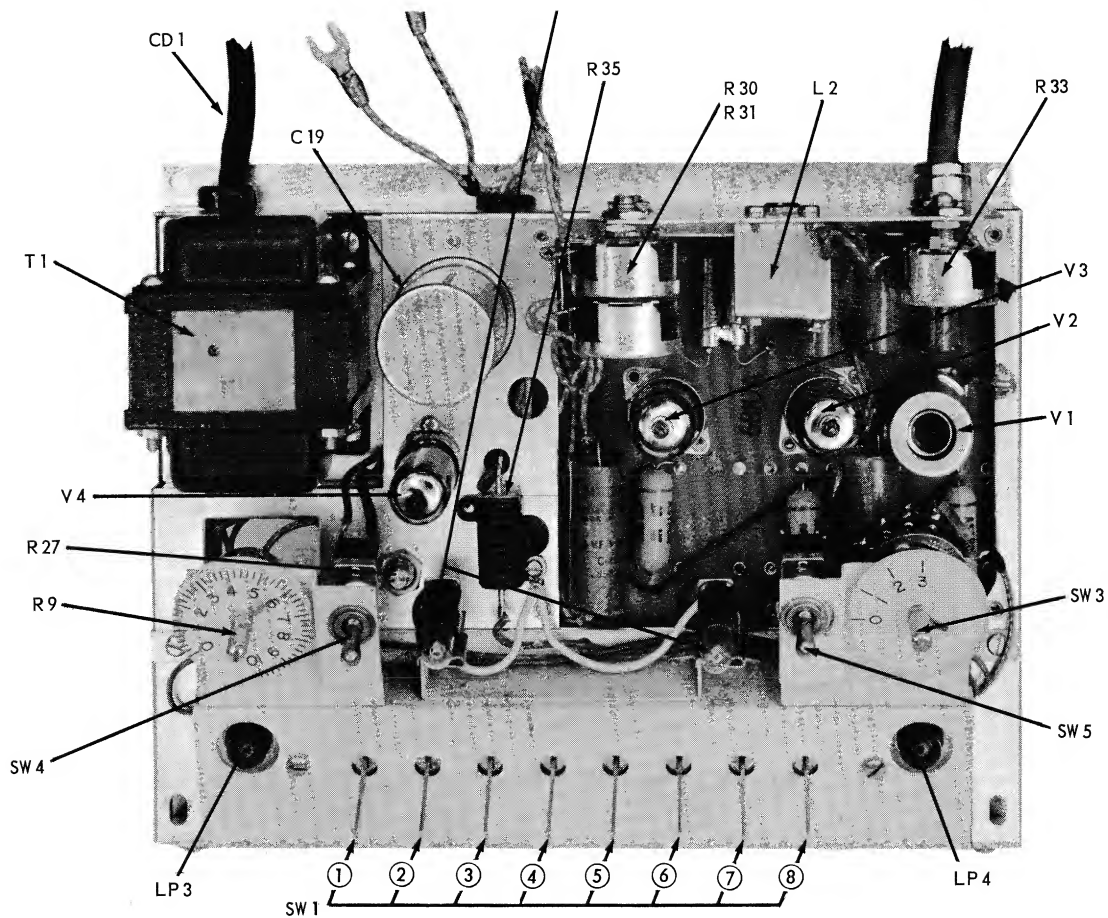


Fig. 8: Top view of Chassis with Components labeled.

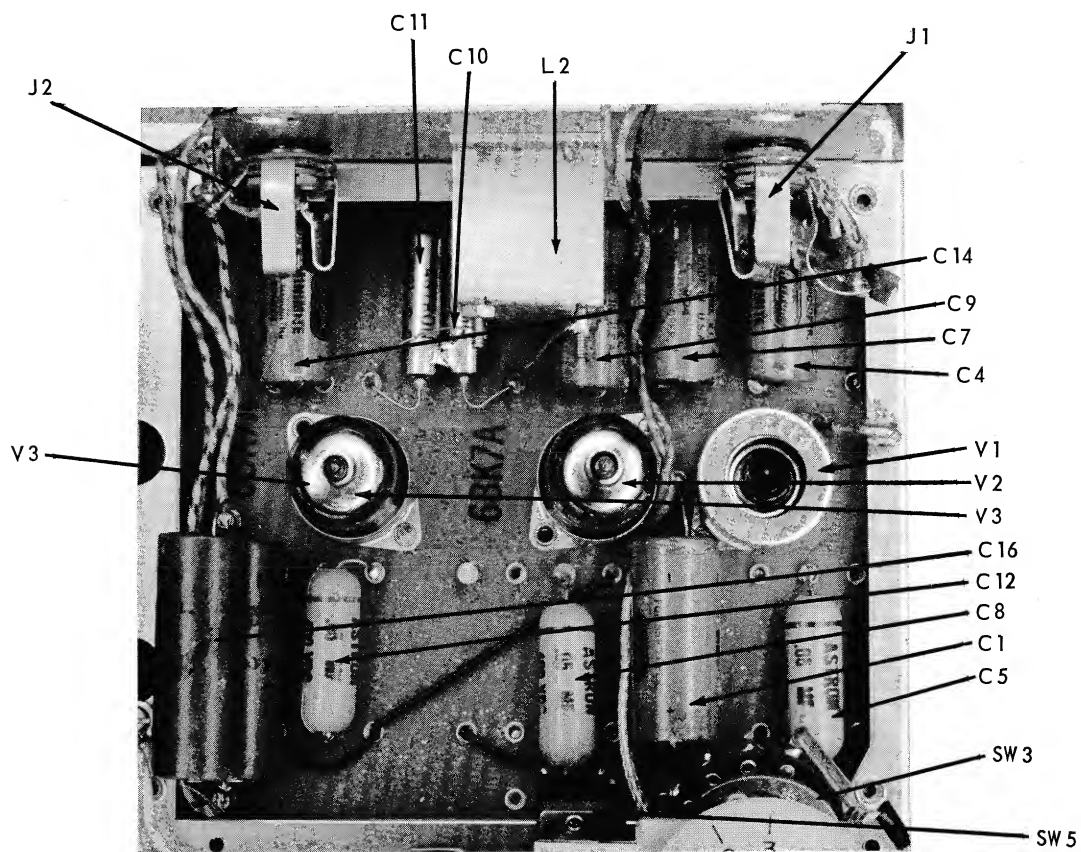


Fig. 9: Enlarged view of terminal board.

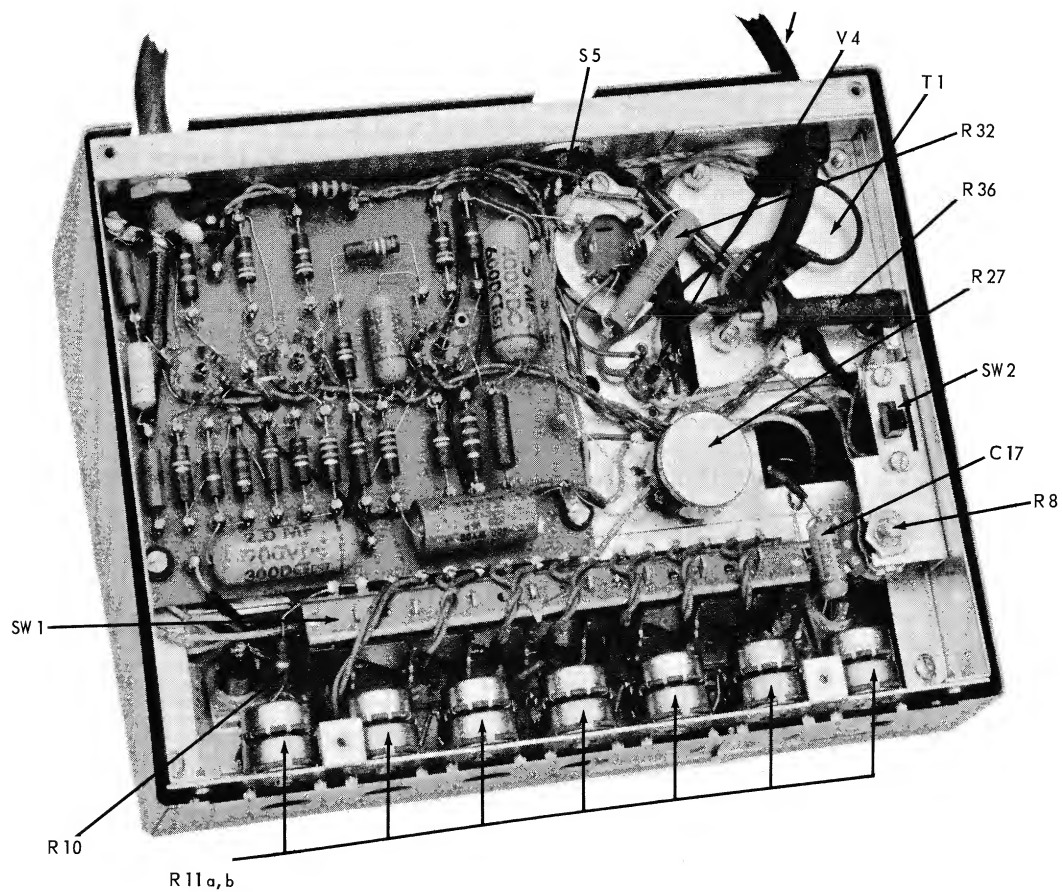


Fig. 10: Bottom view of Chassis with Components labeled.

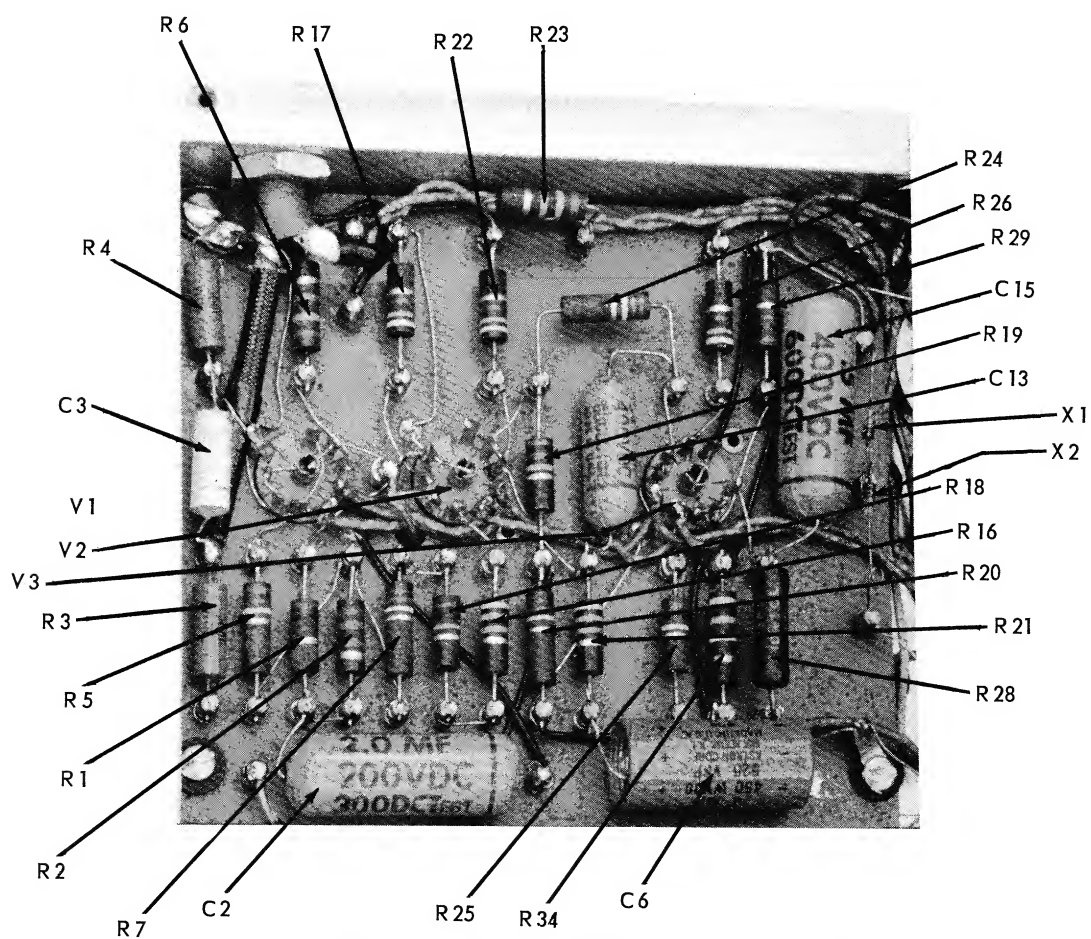


Fig. 11: Enlarged view of terminal board.

SECTION II - TEST EQUIPMENT AND RECORDS

The Welch Densichron Photometer is a very sensitive electronic instrument and in order to properly test performance, diagnose trouble and repair the unit, a suitably equipped and maintained group of instruments are necessary.

1. Minimum Requirement:

The minimum equipment required to apply the tests and corrections recommended in this manual are:

<u>Item</u>	<u>Quantity</u>	<u>Description</u>
1	1	Welch Densichron #3853D Transmission Densitometer
2	2	Welch Calibrated Transmission Step Wedges Cat. No. 3826
3	1	Special Foot Candle Meter available from Welch
4	1	Variable voltage Transformer Welch Cat. No. 2608D or equal
5	1	High Impedance A.C. (Vacuum Tube Voltmeter) Hewlett Packard #400 or equal
6	1	Volt-Ohmeter RCA WV77E Jr. Voltohmyst or WV98B Sr. Voltohmyst or equal

2. Additionally desirable equipment:

The following equipment will permit more accurate and faster service in diagnosing and repairing Densichrons. These are particularly desirable for large firms maintaining repair facilities for a wide variety of Electronic Devices:

<u>Item</u>	<u>Quantity</u>	<u>Description</u>
1	1	Sine wave signal Generator Hewlett Packard #200 CD or equal or
1	1	Special signal generator for Densichron testing by Welch
2	1	Microvolter General Radio No. 546C or equal
3	1	Oscilloscope - 5" - Hewlett Packard No. 120A or DuMont model 304-A or equal

3. Records:

It will be of great value to keep a running record of the maintenance necessary in each Densichron unit. By this means changes in its performance since the last inspection test can be detected and frequently replacement of parts can be accomplished before an actual failure occurs.

It is much easier to detect a weakness in an operating instrument than to detect a defective component when the instrument is inoperable.

The form reproduced below is used on all factory final inspection and repairs, and has proven quite adequate for the purpose. The entries are typical of one instrument record. A new sheet is used each time the unit is repaired.

DENSICHRON RECORD

CAT. NO. _____ SERIAL NO. _____

MODEL NO. _____ P.O. NO. _____

ITEM _____

PROBE SER. NOS. _____

OTHER SER. NOS. _____

CUSTOMER _____

_____ ORDER NO. _____

TOWN _____ STATE _____

INSPECTION BY _____ OK'D _____ DATE _____

MECH. ZERO _____ NOISE VALUE _____ ANODE VOLTAGE _____

HUM LEVEL _____ MULTIPLICATION _____ ANODE DROP RES. _____

MICROPHONICS _____ LIGHT LEVEL _____ ANODE LOAD RES. _____

DRIFT & FATIGUE _____ PHOTO SENSITIV. _____ AMPLIFIER SENS. _____

	TRANSMISSION DENSITIES			LINEARITY TESTS						
	HLLD.	LLLD.	VAR.							
1										
3										
5										
7										
9										
11										
13										
15										
17										
19										
21										

REMARKS _____

4. Procedure:

When maintaining repair facilities for Densichron (as for any precision electronic device) it is best to establish a routine or pattern for this work. By this method a failure can frequently be anticipated and corrected without causing production delays. The following points will guide you in developing a routine that fits your program.

- a. Conduct a daily check on each instrument to see that everything is performing properly. Particularly watch for: (a) fall-off of light on the light source; (b) loss of sensitivity in the amplifier; (c) increase in electrical noise or meter wiggle; (d) accumulation of dirt or dust on the optical parts; (e) a change in the operator's methods. Such a procedure should take about 5 minutes per instrument, and will prevent many emergency service complaints.
- b. When an instrument is received for repair, take the time to go through the testing procedure and record the results in this "as received" condition. Watch these records and try to identify a pattern or repeatable failures. They will be a great help in anticipating the need for repair, or in defining a permanent cure.
- c. Be very diligent about maintaining performance records of each instrument after it has been repaired and ready for return to the user. These records are frequently needed to answer - "How did this instrument behave last time it was repaired?"
- d. In making repairs, economics of parts and labor costs affect the decision on how to correct the fault. On the whole, it's cheaper to simply replace a resistor or condensor than to determine whether that component is actually defective. On more expensive components, such as the transformer, large electrolytic condensers, etc., it is cheaper to take the time to be sure that component is defective. The Electron tubes are in the middle; you must judge for yourself whether it's easier to replace them or thoroughly test them for weakness.

SECTION III - PERFORMANCE

This section describes the tests which should be made to determine whether the instrument is performing satisfactorily, and to indicate routine adjustments to improve its performance. This is presented in a step-by-step procedure. If malfunction is detected when applying this procedure, refer to Section IV for procedure to detect the cause and execute the cure.

1. Meter Zero Check:

Before connecting amplifier to the power line, check to see that meter pointer is free of damage from hard usage. When case is rocked gently, meter pointer should move freely without sticking. It is occasionally necessary to adjust the meter zero signal adjustment.

- a. Rotate adjusting screw on front of meter case until meter pointer rests at electrical zero position (extreme left end of scale).

2. Warm Up:

With power switch in "off" position, set range switch to "O", rotate calibration control to "O", depress push button 8, and plug line cord into 115 voltage 60-cycle wall outlet. Move power switch to "on" position and allow instrument to warm up (15 minutes warm-up is enough for most applications, but a small drift may occur during the first two hours of operation).

- a. Check the dial lights by turning them on. The meter face, range dial, calibration dial and push button number panel should all be clearly illuminated with red light. A dark area indicates one of the dial lights is out and needs replacement.

3. Hum Adjustment:

- a. Cover the probe so that no light enters the aperture. (The blank aperture disc supplied is preferred, but a piece of opaque black paper will suffice.) Set range switch on position "3", calibration control on "10" and depress push button 8.
- b. Rotate "Hum Adjust" potentiometer on rear panel (requires a screw driver be inserted in hole in rear nameplate) until meter pointer is as far to the left as possible. The pointer should be less than one-half the distance between 2.0 density and the left-hand scale limit.

Note: The correct position of the "Hum Adjust" is generally near the middle of the movement range. If this is not the case, stop and check for short circuit to ground in the amplifier heater circuit or in the magnet leads in the probe or probe cable.

- c. Change controls to Range "O", Calibration "O", and observe meter deflection. Pointer should fall on extreme left line on the scale.

4. Microphonics Tests:

In any instrument with high sensitivity and high impedance microphonics do exist. In the Densichron these are kept below an acceptable minimum. The tests for microphonics are subjective and require judgment in their interpretation.

- a. Set Range "3", Calibration "10", Button "8" with no light on the probe.
- b. Tap probe and/or probe cable lightly at several places along its length and observe meter needle deflection. It will rise and fall back to its normal rest position. Try it again with more intensity and flex the cable as well. Lift the cable about 10 inches above the table and drop it.
- c. Strongly rap the top and sides of the Amplifier case (or lift one side about 1" above the table and drop it) and observe the meter deflection. The maximum meter needle "jump" should not be to the right of 1.5 density although a jump as high as 1.0 density is usually acceptable.

5. Setup for further tests:

- a. Connect the amplifier to the light source and allow about 30 minutes warm-up time for both light source and amplifier. Use the 1/8 dia. aperture in light source and be sure the lamp is properly focused (image of filament centered and about 1/8" above the surface of the aperture).

6. Drift and Fatigue Test:

The electronic components of the Densichron are somewhat affected by their previous history of exposure to light (or signal strength). The test for this factor is to "shock" the system with high intensity light and observe its effect on the readings.

- a. Set Amplifier Range "3", Calibration "10", Depress Button "8". Place neutral densities total approximately 4.0 over aperture, lower arm and adjust lamp rheostat so meter reads between .6 and .7 density. Make a note of the actual value of this setting.
- b. Hold step wedge firmly in position and raise arm. This exposes phototube to general room illumination and should cause the meter pointer to move sharply over to the far right hand side (actually bang against the stop). Hold this position for 10 to 15 seconds.
- c. Lower the arm to its reading position on the step wedge and observe the meter behavior. It should return exactly to the previous setting and stay there. Drift and fatigue are evidenced when the meter returns to a position close to the original setting, hesitates for a few seconds and then slides over to a new reading (usually the original setting). This indecision should not exceed .02 density in either direction.

Note: A delayed movement to a higher density is drift. A delayed movement to a lower density is fatigue. Assuming the original setting was .65 density, then drift will usually be observed by the pointer quickly returning to .63 density, hesitate, and then move over to .65 density. Similarly, fatigue will usually be observed by the pointer quickly returning to .67 density, hesitate, and then move over to .65 density.

- d. If drift does appear, then reduce the density of the step wedge by approximately .6 density and adjust the calibration control so the meter again reads the original value. Again raise and lower the arm and observe the meter behavior. The drift should virtually disappear.

7. Multiplication or Range Switch Test:

A properly working range switch changes the amplifier sensitivity by a factor of 10 or 1.0 density in the meter.

- a. Set Amplifier Range "0", Calibration "6", push button "8" and adjust light level so meter reads 0.0 density.
- b. Place approximately 1.0 density on the aperture, change to Range "1" and readjust light level so meter again reads 0.0 density. Change range to "0" and record meter reading.
- c. Repeat with approximately 2.0 density on Range "2" and record reading.
- d. Repeat with approximately 3.0 density on Range "3" and record reading.
- e. Compare the range switch errors above. If errors are in excess of $\pm .01$ density and generally in the same direction, adjust the "Multiply Adjust" on the rear panel to bring the readings within the $\pm .01$ tolerance.
- f. If the errors vary greatly on different ranges, or if there is not enough adjustment in (5) above, return the instrument to the factory for repair.

8. Photometric Sensitivity:

Each Densichron is calibrated to produce approximately the same photometric sensitivity to white light. To do so the amplifier sensitivity is adjusted to compensate for variations in phototube sensitivity.

- a. Set Amplifier Range "0", Calibration "10", Push Button "8", and set light level so meter reads 0.5 density.
- b. Raise probe arm and measure intensity of the light with special foot candle meter. This reading should be 5 foot candles.
- c. If the deviation from 5 foot candles is small (between 3 and 7 f.c.) a correction can be made by adjusting the internal sensitivity control (R-8) (a screw driver adjustment accessible through the hole in the bottom of the amplifier). If there is not enough adjustment available, the unit must be serviced to correct the fault.

9. Linearity Test:

This test is made by checking the instrument's ability to read correctly a step wedge calibrated in ASA Diffuse Densities. Since the components of the photometer are not perfect, exhibiting anomalies due to light level change or component non-linearities, it is necessary to standardize the method of checking so that tests made at different times will produce comparable results.

- a. Set Amplifier Range "0", Calibration "10", Push Button "8", and adjust the light level so that meter reads 0.0 density.

- b. Back off the calibration control until meter reads 0.3 density and readjust light level to again read 0.0 density.
- c. Insert the calibrated step wedge over the aperture and measure the density of each step. Record these measurements and label them as High Light Level Densities. (You can save a little time by reading every other step.)
- d. Change amplifier sensitivity by switching to range "1" (do not change calibration control) and readjust light level so that meter again reads 0.0 density. (This is a new starting point and 1.0 must be subtracted from all readings to obtain true density.)
- e. Again insert the calibrated step wedge over the aperture and measure and record the density of each step. Label these Low Light Level Densities.
- f. Tabulate above readings and compare them to the calibrated wedge and to each other as follows:

Column A - Calibrated Step Wedge Density
 Column B - HLLD Value
 Column C - Difference between A and B
 Column D - LLLD Value
 Column E - Difference between A and D
 Column F - Algebraic difference between C and E

Acceptance limits for above differences are:

Density Range	Tolerance For Column C or E	Tolerance For Column F
0.0 - 0.5	$\pm .01$	.02
0.5 - 1.0	$\pm .015$	.03
1.0 - 1.5	$\pm .02$	.04
1.5 - 2.0	$\pm .025$	.05
2.0 - 3.0	$\pm .03$	.06
3.0 and up	$\pm .04$	.08

Note: Interpretation of the measured differences and of the tolerances is important. Familiarity with performance of many instruments will help in judging whether to accept or reject the performance. Here are some things to consider:

1. The light source itself, since the light incident on the sample is not truly collimated, tends to produce higher densities for the high density end of the step wedge. This can be minimized by proper focus of the optical system.
2. The test conditions for HLLD and LLLD have been selected from experience and it is usually true that, while both of these readings may be quite far off the true value, there is some intermediate light level where the instrument will read within the tolerances.
3. There is a tendency for the LLLD readings to be higher than the HLLD readings. The HLLD readings tend to be too low on the first few steps and then to level off to a constant error or even to come back to a zero or plus error. Reducing the light level usually reduces this tendency.

4. If one or two readings are outside the tolerance, first check the reading to be sure there is no mistake, then check the calibrated standard for "pinhole" scratches, or particles of dirt.
5. Do not accept the performance when the readings frequently vary from one extreme of the tolerance to the other.

10. Voltage Compensation:

The Densichron circuit incorporates circuitry which compensates for small variations in line voltage. The degree of compensation may change a little as the tubes age and emission drops.

- a. Insert an adjustable Voltage Transformer between the Densichron Amplifier and the power line (do not power the light source through the transformer). Adjust transformer to deliver 118 volts under load.
- b. Set amplifier controls to Range "0", Calibration "6", Push Button "8" and adjust light level to read .10 density on the meter.
- c. Vary amplifier voltage between 105 and 125 volts and observe meter movement. Pointer should remain within $\pm .02$ density of original setting, and it will take a few seconds for the meter to adjust to the new voltage (when voltage is changed rapidly from one extreme to the other, the meter may overshoot the new position and then settle out within $\pm .02$ density).

11. Push Buttons and Controls:

Each push button and its potentiometer should be tested to see that no malfunction exists.

- a. Set Amplifier controls at Range "0", Calibration "10", Push Button "8" and adjust light level so that meter reads approximately .10 density. Rotate all controls in the potentiometer bank to full clockwise position.
- b. Depress Push Button "1" and rotate outer section of Control "1" in counter clockwise direction. Meter pointer should move almost to extreme left-hand mark on the dial. Return to original position and rotate inner section full counter clockwise and observe meter movement. Pointer should move about .20 density.
- c. Repeat (b) with Push Buttons 3, 4, 5, 6 and 7.

12. External Attenuator Check:

The jack on the back panel marked "External Attenuator" permits the use of remote attenuators selected by means other than the push buttons.

- a. With same setup as (11) above, insert remote attenuator cord in amplifier and light source, and depress button "8".
- b. Select one or two filter positions on the light source, adjust light level to read approximately .10 density and rotate the appropriate filter potentiometer on the light source panel. Meter should behave the same as in (11) above.

13. Miscellaneous:

- a. Turn dial lights on and check to see all lamps are burning. There are four of them: two illuminating the meter and range and calibration dials; and two of them are illuminating the push button panel.
- b. Place your hand on top of the case to be sure it's not too hot. It should be quite warm, but not uncomfortably hot to the touch.
- c. Visually inspect the case, meter pointer, push button panel, etc., to be sure no physical damage has occurred.
- d. Check to make sure apertures, aperture wrench, special tool for push button controls and any other separate parts are not lost.

14. Variations Due To Application:

The above test procedure and performance limits have been selected to provide the best over-all quality of a general purpose photometer. In any particular application certain compromises are possible which might improve the instrument's usefulness. There are both advantages and disadvantages in this practice, because increasing one useful characteristic will mean also increasing a detrimental characteristic. Following are a few such "tricks" that can be used and the precautions necessary:

- a. To get more sensitivity:

This is sometimes desirable when using the smallest apertures or special narrow band filters. The photometric sensitivity of the instrument is the combination of phototube sensitivity and Amplifier gain. To increase the sensitivity it is necessary to select a higher sensitivity phototube and/or to increase the amplifier gain (adjustment through bottom of chassis). Either one of these changes might also increase the minimum hum level which, in turn, would produce an error in linearity at the higher densities (maximum sensitivity setting). The only thing to do is try it and see if the increased hum wipes out the advantage of increased sensitivity.

- b. Improved instrument to instrument agreement:

Based on the above performance criteria, it is possible to have two instruments that have inherent inaccuracies that are opposed resulting in the maximum tolerance on instrument differences. There are several things that can be done to help this situation, all of which amount to distributing the difference so they average out to a smaller value.

1. Adjust the light level on the two light sources in such a way as to produce a small amount of overload and, therefore, error in the lower densities. By juggling the two settings the differences at high density values can be reduced.
2. Adjust the multiplying on each amplifier so that neither one is quite correct, usually one unit too short and one unit too long. In this way the difference is partially compensated at each range step, growing to a maximum at densities of about .9, 1.9, 2.9, etc. If you go too far with this, you will begin to pick up larger mid-scale errors and will lose that which you are trying to gain.
3. The differences in two instruments are greater when using filters (particularly the red). The units can be brought closer together by selecting phototubes for color response. This is a trial and error selection for performance. It is expensive and should be avoided if possible.

SECTION IV - SYMPTOMS - THEIR CAUSE AND REMEDY

In using the information in this section of the instructions, it will be necessary to frequently refer to the circuit diagram. If there is doubt as to the location of a component in the chassis, then refer to figures 5 through 11 in Section I.

This section has been prepared in outline form and serves as a guide for trouble shooting and repairing the Densichron 2 Photometer. It will be realized that every possible trouble that might occur from prolonged usage cannot be anticipated. As problems, not listed in this section come up, insert a sheet into the instruction for future reference. The outline is arranged as follows:

1. The Symptom:
 - a. Most probable cause
 1. Test and/or cure
 2. Test and/or cure
 - b. Second probable cause
etc.
1. Inoperative on all ranges - dial lights won't burn.
 - a. Open circuit in power cord.
 1. Check plant fuse in power line.
 2. Check resistance between prongs of line cord plug (CD-1); if circuit is open check visually for a broken connection.
 3. Check power on "off" switch (SW4) for open circuits in "on" position.
 - b. Open circuit in power transformer.
 1. Disconnect primary leads (black of power transformer (T-1) and check for open circuit. Replace if defective.
2. Very little or no signal - Power Transformer overheats and you can sometimes smell varnish.
 - a. Short in the low voltage circuits.
 1. Remove all tubes and check for shorts. If O.K., replace tubes in same socket from which they were removed.
 2. With power on, check RMS voltage between pins 1 and 2 of receptacle in back panel. If it is not 6.0 to 6.3 volts, the short is in the dial lamp circuit.
 3. Check pins 3 and 4 of tube V4. If this is not 6.0 to 6.3 volts, the short is in the heater circuit of the rectifier tube.
 4. Check pins 4 and 5 of tubes V1, V2, or V3. If this is not 5.5 volts, the short is in the heater and magnet circuit.
 5. Disconnect one end of Resistor R36 and check voltage between contacts 1 and 2 of switch SW2 (switch in tungsten position). If this is not 6.3 volts, the short is in the magnet circuit.

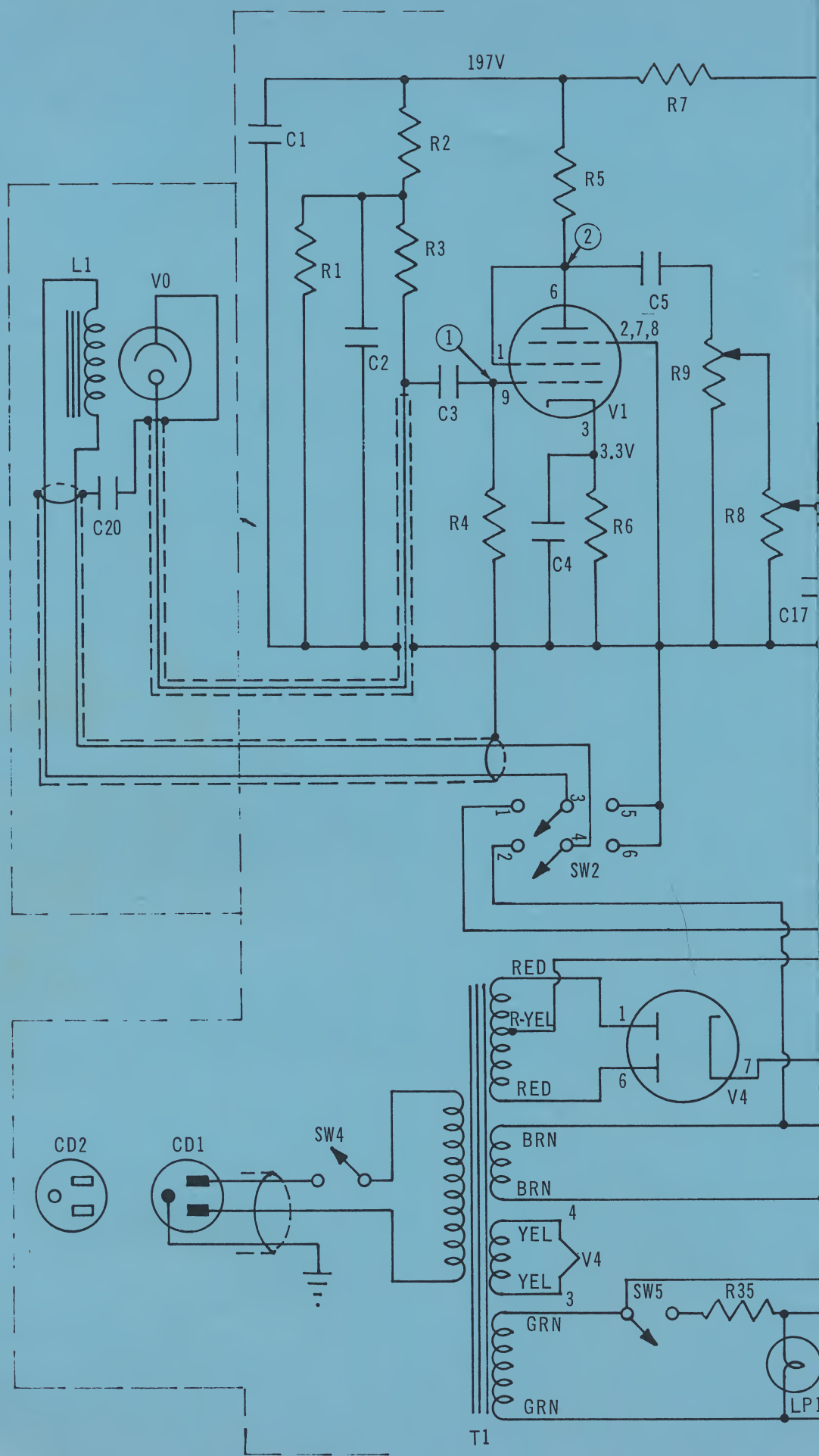
3. Very little or no signal - dial lights O.K. - no overheating of transformer.
 - a. Broken Phototube.
 1. Open Probe (see Fig. 7) and visually examine Phototube. Cathode surface should be grey to black (brown tint) in color. If distinctly dark red or rust colored a crack or gas leak exists.
 - b. Short in high voltage DC circuits.
 1. Check 6202 Rectifier (V4) for damage.
 2. Check Filter Condenser (C19) for short.
 3. Check Decoupling Condensers (C1, C2, C6) for shorts.
 - c. Loss of gain in Z729 (V1) Tube.
 1. Check AC signal voltages or replace tube.
4. Very little signal - high noise level.
 - a. Cathode to grid leakage (positive grid) on 6BK7B Tubes (V2 V3)
 1. Remove tubes and test for leakage
or
DC voltage on pins 7 and 2 should be zero; if voltage is positive, tube is defective.
5. High hum or noise level - cannot adjust zero signal to an acceptable value.
 - a. Short circuit or leakage to ground in amplifier heater circuit or in magnet leads to probe.
 1. See "b" above for tests.
 - b. Defective shielding in probe cable and/or connections to phototube and to grid of first stage (V1).
 1. Place metal disc in probe aperture and attach clip leads between strain relief on probe and on amplifier. If hum drops to normal value, there is a discontinuity in the probe cable shielding. Check for poor ground connection at both ends of the cable, or replace cable.
 - c. Defective cathode bypass condenser.
 1. Disconnect cathode bypass condensers (C4, C7, C9, C14) and check AC signals at the cathode (pin 3 on V1, pins 3 and 8 on V2 and V3) should be zero volts AC.
 - d. Noisy 6BK7B in V2 position (occasionally V3).
 1. Test 6BK7B for shorts or replace with new tube.
 - e. Open or noisy Grid Resistor (R4) or Phototube Load Resistor (R3).
 1. Remove and replace both Resistors.

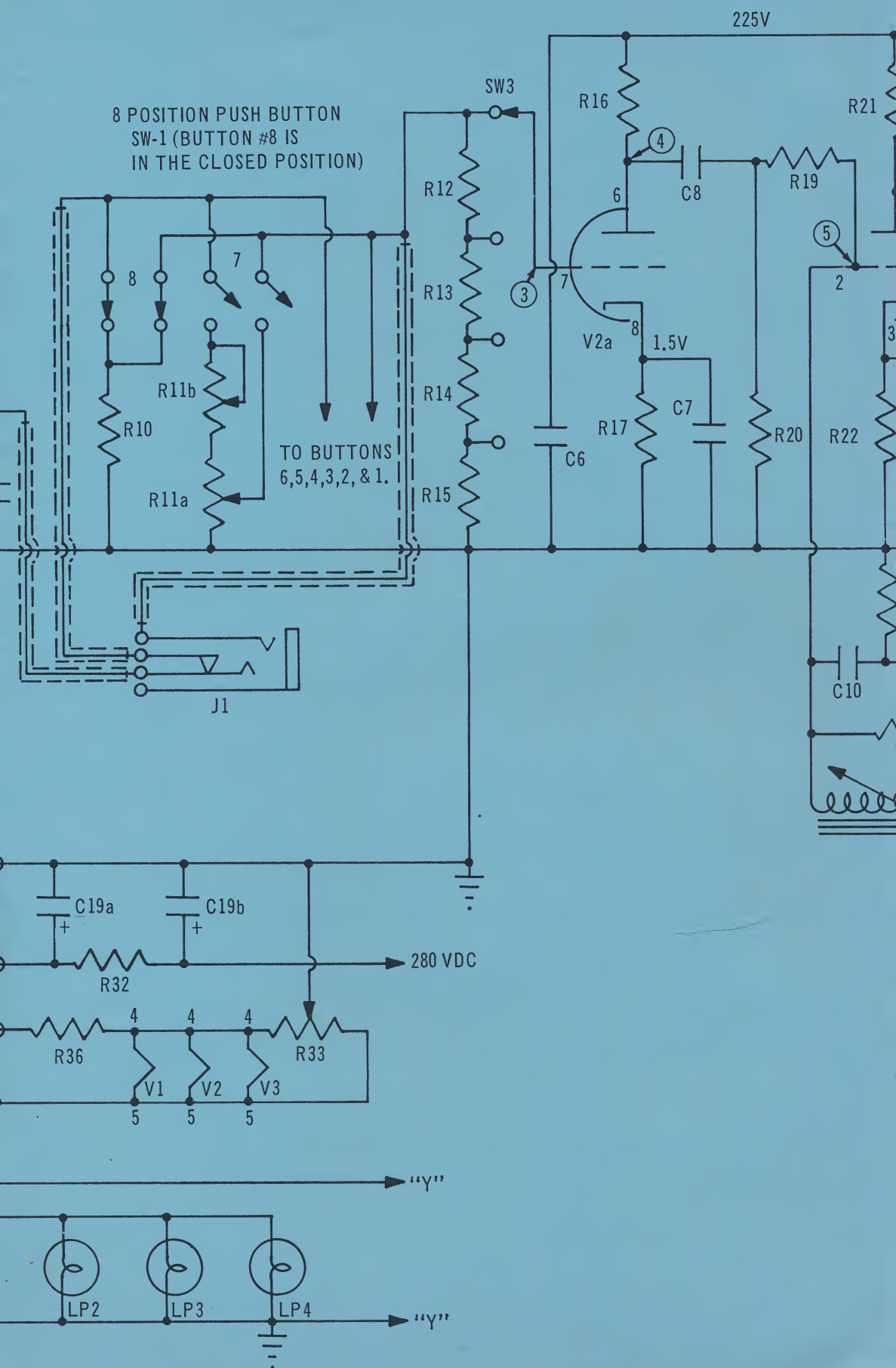
6. Densichron Range "0", no light on Probe, meter indicates definite signal.
 - a. Leakage in Filter Condenser (C19).
 1. Check resistance across each section of Filter Condenser (C19).
7. Low sensitivity - Large decade stepping error.
 - a. Apply 120 cps signal to grid of Z729 (pin on V1) and adjust choke (L2) to produce maximum meter deflection. (Adjust to both sides of the peak and then set adjustment at the midpoint). Tap choke with end of screwdriver to make sure it will remain as adjusted. If not, replace the choke.
8. On Range 3, sufficient signal to indicate approximately .8 density, meter oscillates wildly (approximately $\pm .10$ density).
 - a. Defective Bypass Condenser (C2).
 1. Remove and replace.
 - b. Noisy or shorted Z729 Tube (V1).
 1. Try a new tube.
 - c. Feed back loop out of adjustment.
 1. Apply a 150 microvolt 120 cps signal to grid of Z729 (V1); all controls set for maximum sensitivity, adjust Potentiometer R27 so that meter reads full scale.
9. Meter fluctuates when Probe or Probe Cable is tapped. Amplifier on Range 3. Does not occur when amplifier case is tapped.
 - a. High microphonics in probe or probe cable.
 1. Return to factory for repair.
10. Meter fluctuates when Amplifier case is tapped. Amplifier control on Range 3. Tapping Probe Cable does not cause excessive fluctuation.
 - a. High microphonics in the amplifier.
 1. Check each tube by tapping its envelope or shield and replace defective ones.
 2. Check all components and leads to grid of first stage (V1) to be sure they are rigidly held in place.
 3. Check choke (L2) for stability of adjustment and replace if defective.
11. When exposed to light, meter does not go upscale.
 - a. Defective amplifier tube (loss of gain).
 1. Check AC signal voltages for discontinuity and replace defective component.
 - b. Open circuit in plate supply voltages.
 1. Check DC plate voltage and correct any discontinuity.

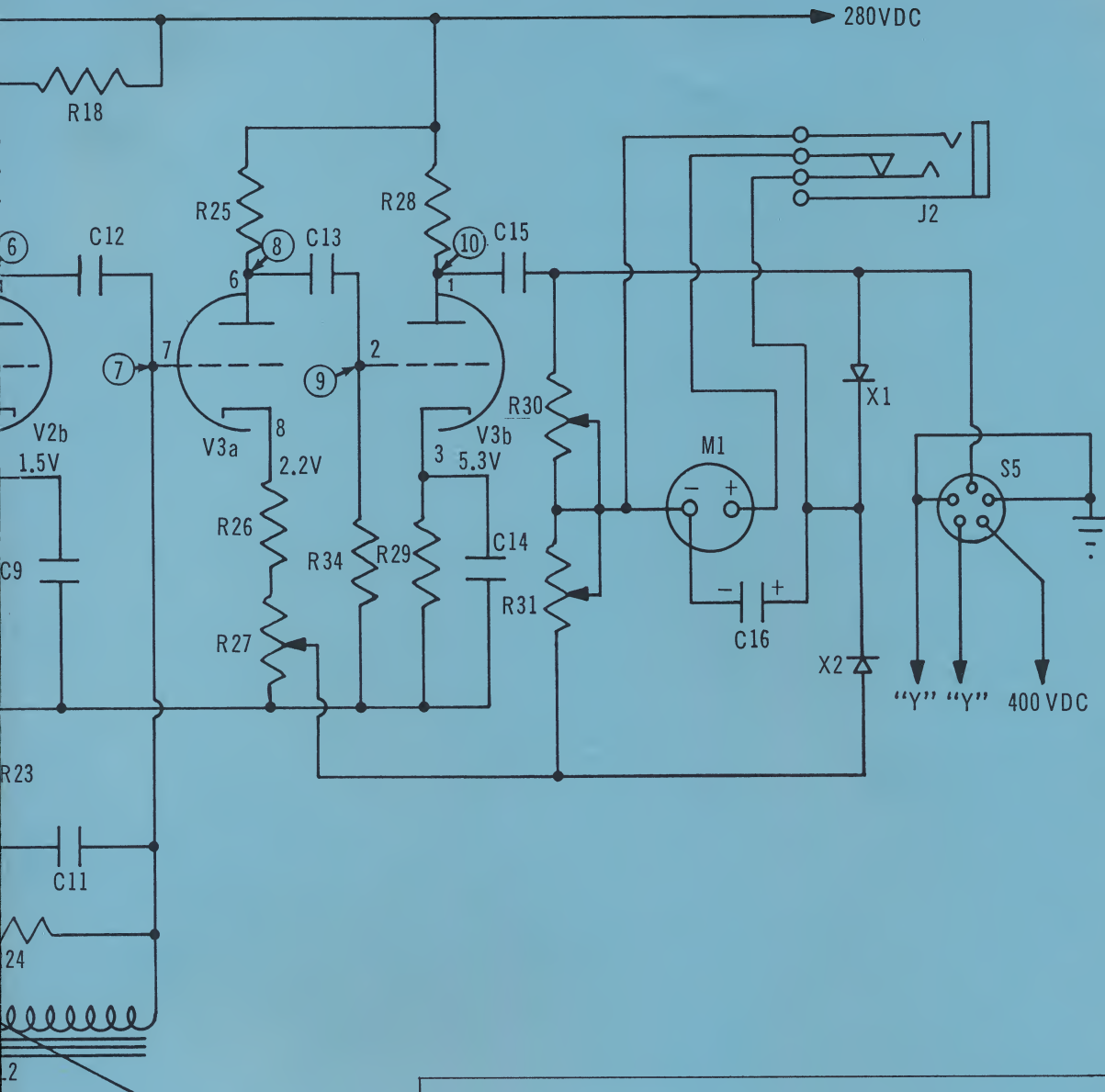
12. Intermittent and sudden loss of signal.
 - a. Short in Z729 (V1) Amplifier Tube.
 1. Remove and replace - check tube on tube tester and tap tube to confirm short.
13. Meter apparently sticks in one position.
 - a. Meter pivots damaged or out of position.
 1. Tap case lightly and at same time alternately apply and remove a fairly large signal. If sticking continues, return meter to factory for repair.

Item	Piece No.	Description	Item	Piece No.	Description
C1	1857	4 MFD 450 WVDC Electrolytic	R10	1958	1 Meg. 10% 1W Ins. Carbon
C2	1893	2 MFD 200 WVDC Metalized Paper	R11a	3216	1 Meg. 10% 1/2W Carbon Pot.
C3	1796A	.01 MFD 600 WVDC Mylar	R11b	3216	100K 10% 1/2W Carbon Pot.
C4	1792A	25 MFD 25 WVDC Electrolytic	R12	1743	900K 1% 1W Metalized Film
C5	1757	.05 MFD $\pm 10\%$ 400 WVDC Paper	R13	1744	90K 1% 1W Metalized Film
C6	1857	4 MFD 450 WVDC Electrolytic	R14	1745	9K 1% 1W Metalized Film
C7	1792A	25 MFD 25 WVDC Electrolytic	R15	1746	1K 1% 1W Metalized Film
C8	1757	.05 MFD $\pm 10\%$ WVDC Paper	R16	951B	47K 10% 1W Ins. Carbon
C9	1792A	25 MFD 25 WVDC Electrolytic	R17	1992G	470 ohm. 10% 1W Ins. Carbon
C10	3198	.22 MFD 200 WVDC Metalized Paper	R18	1956	10K 10% 1W Ins. Carbon
C11	3198	.22 MFD 200 WVDC Metalized Paper	R19	1968	22K 10% 1W Ins. Carbon
C12	1725	.1 MFD 400 WVDC Metalized Paper	R20	1957	220K 10% 1W Ins. Carbon
C13	1757	.05 MFD $\pm 10\%$ 400 WVDC Paper	R21	951B	47K 10% 1W Ins. Carbon
C14	1792A	25 MFD 25 WVDC Electrolytic	R22	1992G	470 ohm. 10% 1W Ins. Carbon
C15	1726	.5 MFD 400 WVDC Metalized Paper	R23	1969	27K 1W Ins. Carbon
C16	1992Q	100 MFD 25 WVDC Paper	R24	1957	220K 10% 1W Ins. Carbon
C17	1797	.005 MFD 600 WVDC Paper	R25	2088	100K 10% 1W Ins. Carbon
C18	1992Q	100 MFD 25 WVDC Electrolytic	R26	1992G	470 ohm. 10% 1W Ins. Carbon
C19a	1723	40 MFD 450 WVDC Electrolytic	R27	1992P	500 ohm. 2W W.W. Pot.
C19b	1723	40 MFD 450 WVDC Electrolytic	R28	1988S	15K 10% 5W Wire Wound
C20	2272	.0001 MFD 500 WVDC Molded Mica	R29	1951	1K 10% 1W Ins. Carbon
CD1	1772A	3-Wire Cord Set with Plug	R30	1887	10K 2W Pot.
CD2	537D	Grounding Receptacle Plug	R31	1887	10K 2W Dual Pot.
J1	1988N	3-Circuit Jack	R32	1815A	10K 10W Wire Wound Moulded Resistor
J2	1988N	3-Circuit Jack	R33	3229	200 ohm. 2W Wire Wound Pot.
L1	1991	Magnetic Yoke	R34	951C	470K 10% 1W Ins. Carbon
L2	3221	Variable Inductor	R35	3227	Resistor 5 ohm. 25W 10% W.W.
LP1	1771	Dial Light G.E. #47 Bayonet Base	R36	3109	Resistor .8 ohm. 10W 10% W.W.
LP2	1771	Dial Light G.E. #47 Bayonet Base	SW1	3199	8 Position Push Button Switch
LP3	3222	G.E. #328 Miniature Lamp	SW2	3226	2 PDT Slide Action Switch
LP4	3222	G.E. #328 Miniature Lamp	SW3	3220	4 Position Rotary Switch
M	1749E	Meter IMA, w/Log Color Comp. Scale	SW4	1988K	SPST Toggle Switch
R1	1958	1 Meg. 10% 1W Ins. Carbon	SW5	1988K	SPST Toggle Switch
R2*	1950A	15 Meg. 10% 1W Carbon	T1	1992H	Power Transformer
R2*	1964	12 Meg. 10% 1W Ins. Carbon	V0	1720C	934 Phototube (Selected)
R3	1988T	20 Meg. 1% 1/2W Dep. Carbon	V1	3197	Z 729 Pentode Electron Tube
R4	1988T	20 Meg. 1% 1/2W Dep. Carbon	V2	3169	6BK7-B Twin Triode Vacuum Tube
R5	1957	220K 10% 1W Ins. Carbon	V3	3169	6BK7-B Twin Triode Vacuum Tube
R6	1955	6800 ohm. 10% 1W Ins. Carbon	V4	1992E	GL 6202 Tube Full Wave Rect.
R7	1957	220K 10% 1W Ins. Carbon	X1	3110	Diodes Matched Pair
R8	3219	1 Meg. 20% 1/2W Carbon Pot.	X2	3110	Diodes Matched Pair
R9	3234	1 Meg. 20% 1/2W Carbon Pot.	S1	1988P	Miniature Bayonet Dial Light Socket
			S2	1988P	Miniature Bayonet Dial Light Socket
			S3	3217	Min. Dial Light w/Red Plastic Dome
			S4	3217	Min. Dial Light w/Red Plastic Dome
			S5	3228	5-Pin Bakelite Socket
			S6	1988L	Min. Tube Noval 9-Pin w/Shell
			S7	1998L	Min. Tube Noval 9-Pin w/Shell
			S8	1988L	Min. Tube Noval 9-Pin w/Shell
			S9	1988M	7-Pin w/Shell Min. Tube Socket

* Actual value is selected at final assembly.







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3	.004 volts
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5	.027 volts
6	.66 volts
7	.63 volts
8	1.20 volts
9	1.20 volts
10	6 to 13 volts



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